Oxford Cambridge and RSA Examinations

OCR

ADVANCED GCE
ADVANCED SUBSIDIARY GCE

A2 7888
AS 3888

PHYSICS B
(ADVANCING PHYSICS)

MARK SCHEME FOR THE UNITS
JANUARY 2004

AS/A2
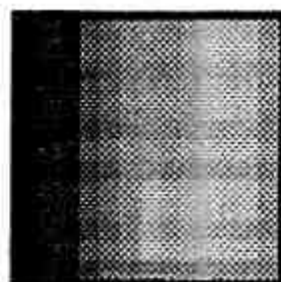
3888/7888/MS/04J

Mark Scheme 2860
January 2004

Abbreviations, annotations and conventions used in the Mark Scheme	/	= alternative and acceptable answers for the same marking point
	;	= separates marking points
	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	___	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

Qn	Expected Answers	Marks	Additional guidance
1a;b	**Section A** V ; C s^{-1}	2	
2a;	32 ;	1	
bi;	(samples/sec x bytes/sample x time) / 44.1 x 10^3 x 4 x 150 method ; = 26.4(6) Mbytes ; eval.	2	allow 25.2(3) Mbytes pc correct eval. scores 2
ii	(data) compression / fewer samples/sec / fewer bytes/sample / reduce quality / AW	1	other sensible comments NOT filtering
3 a;b;c	metal ; rubber ; glass	3	
4a;b c	0.13(0) m ; 8.33 / 8.3 ; ± 0.3 / 0.4 D ecf on (b)	2 1	accept 0.33 or 0.31 or 0.32 or 0.34
5ai;ii	3 ; 8 / 2^3	2 1	NOT 7
bi ;	50 mV	1	accept 100 mV
ii	more (than 3) bits (per sample) / more levels / better voltage resolution AW		NOT greater sampling rate
6ai;ii	x ¼ ; x 2	2	
7

more bass   less treble | 1

1 | zero marks for no attempt

In col. 1 accept 2/3/4 bass bars

In col.5 expect 0 treble bars / OR

(accept 0/1 bars in col. 4) |
| | **Section A total** | 20 | |

Qn	Expected Answers	Marks	Additional guidance
	Section B		
8a	decreases / falls / drops ; 100 ($\pm$ 10) ; low(er) / 22 °C	3	"30 to 40°C" / (value in range) 20 - 30 °C
bi	connections in parallel with fixed resistor	1	
ii	$R_{Thermistor}$ = 100 to 105 (Ω) ;	1	evidence from graph
	R_{Total} = 200 + $R_{Thermistor}$ (Ω) ;	1	total resistance
	$I = (V / R_{Total}) = 6 / R_{Total}$ (= 0.02 A)	1	substitution ora
iii	$(V = I R = 0.02 \times 200) = 4.0$ V	1	ecf R from b(ii)
		1	accept 4 V
ci	X ;	1	
ii	advantage (near) constant sensitivity / linear (output)	1	NOT "just" straight line allow AW or other sensible quality physics
	disadvantage less sensitive (over most of range) / range of voltages is small / battery lasts for less time	1	
9a	$\lambda = v / f$; = 1500 / 8000 ; = 0.19 m	3	allow $v = f\lambda$ recall 1st mark
	ora $v = 1600$ m s^{-1} is about 1500 m s^{-1} full marks		
b	$t = s / v$ / = 5000 / 1500 ; = 3.3 s	2	2 marks correct answer
c	t = info / rate / = (1500 x 8) / 2400 ; = 5.0 s	2	words / numbers ; allow 1 mark for 0.63s
d	1/2/3 style look for: time delay, live video needs larger info rate, large amount of information, still pictures can be slowly built up, stored at receiving computer	3	AW if good physics NOT "it" is too slow expect quality reasons for the 3nd mark
10a	**brittle:** shatters (on impact) / cracks (propagate) / no plastic region ;	1	AW for all these or other correct physics
	hard: difficult to scratch / dent ;	1	
	strong: large breaking stress ;	1	NOT large yield stress
	tough: difficult to crack / large energy to break / create new surface	1	accept not brittle IF brittle correct OR v.v.
bi	x 4 / much tougher ;	1	NOT just tougher
ii	(toughness is) energy ; per (new surface) area ;	2	
ci ; ii	B ; tougher than A / less tough than C / stronger than A / less strong than C / about ¾ of the strength of C	2	one correct reason or any combination / other correct physics
11a	to reflect light back / up ; to increase illumination	2	AW
b	$P = 1/f$ OR = $1/v - 1/u$; = 1/ 0.4 - 1/ (-0.1) ;	2	3 marks correct value
	= 2.5 + 10 = 12.5 ; D	2	1 mark for unit D
c	transparency : to allow light to transmit /	2	AW
	high refractive index ; to allow thinner lens /	2	allow all sensible
	high melting point : to withstand temperature /		physics answers with
	low density ; to reduce weight of lens /		correct explanation
	strong / tough / hard / stiff etc ; correct reasoning		NOT economics
	Total B	40	

Qn	Expected Answers	Marks	Additional guidance
	Section C		
12ai	student choice sets appropriate context – no marks	0	
ii	any shape of constant cross section ;	1	
iii	(good conductor) : long / thin for measurable R / G / (low E) : short / "fat" for measurable extension / constant cross-sectional area	1	
iv	Two sensible lab estimates: length ; diameter / width / thickness / area	2	
v	Micrometer / Vernier caliper / (travelling) microscope ; justification - need greater precision (accept accuracy)	1 1	allow rulers down to 10mm
bi	A practical difficulty identified e.g. very small extension in stiff material / small resistance in a good conductor	1	accept other sensible suggestions and solutions
ii	solution to difficulty – long specimen ; more relevant detail – repeat readings / averaging	1 1	
ci	For Y expect force ; extension / for σ expect p.d. ; current / Resistance	2	accept standard symbols $R = V/I$
ii	Correct words / symbols ; combined correctly e.g. $Y = Fl /Ae$ / $σ = Il / VA$	2	accept a complete set of equations
13a	imaging system example: e.g. satellite imaging system ; 3 obs: e.g. cloud cover ; sea temperature ; land use	1 3	expect descriptions
bi	waves / radiation : infra-red ;	1	
ii	how data obtained: e.g. low polar orbit covers whole Earth in ½ day satellite scans Earth building up infra-red images infra-red energy detected by photodiode which gives a p.d. in proportion to pixel value on image	3	1/2/3 style full marks for well annotated diagram
ci	resolution is length represented on object / pixel ; NOT the number of pixels	1	AW e.g. smallest resolvable detail
ii	5 km on Earth / pixel ; UP	1	allow ± 1 order of mag.
d	false colour could be added to image, infra-red has no colour, but pixel value ranges can be given colour to represent intensity. This makes images easier to interpret.	3	1/2/3 style give credit for connecting physics
Q of WC	Total C	4 30	

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January 2004

Qn	Expected Answers	Marks	Additional guidance
1 (a)	600 ✓	1	
(b)	60 ✓	1	
(c)	0.6 ✓	1	
2(a)	g.p.e. to k.e. ✓	1	
(b)(i)	$v^2 = 2 \times 9.8 \times 2.8$ ✓ $v = 7.4\ (m\,s^{-1})$ ✓ (g = 10 gives 7.48)	2	By energy change or by suvat
(ii)	neglecting/negligible/no air resistance ✓ (all gpe goes to ke) (constant 'a' if suvat approach)	1	not wind resistance
3(a)	representation of 3 fringes minimum ✓ equispaced peaks ✓ (4 needed)	2	intensity variation is fine
(b)	fringes further apart ✓	1	
4 (a)	$f = (3 \times 10^8) / 1500$ ✓$_m$ $= 2.0 \times 10^5\ (Hz)$ ✓$_e$	2	
(b)	method mark $(2.4 \times 10^{17}) / (2.0 \times 10^5)$ ✓$_m$ $= 1.2 \times 10^{12}$ ✓$_e$ ecf from (a)	2	not 1.2E12 /1.2^{12}
5(a)	horizontal $= 300 \cos 50° = 192.8$ ✓$_m$	1	
(b)	$P =$ (horizontal component from (a)) $\times 0.6$ ✓$_m$ So P = 116 (120) (W) ✓$_e$ (120 W from F = 200 N)	2	penalise using wrong F
6(a)	phasor arrow pointing to S.E. ✓	1	
(b)	same amplitude and wavelength ✓ 180° phase diff ✓	2	**minimum** of 1 cycle
	total	20	

7(a) (i)	destructively interfering ✓	1	phasors antiphase / waves out of phase
(ii)	mention path difference ✓ $\lambda/2$ idea ✓	2	phasors cancel resultant phasor = 0 so probability=0 or AW
(iii)	* (LOOK AT (a)(i) and (ii) together) idea that 2 amplitudes different ✓ cause (absorption) or effect .. not complete cancelling ✓ (others possible)	2	not quite out of phase = 0
(b)	white = many **colours** ✓ green not reflected ✓ other wavelengths give the purple colour✓	3	not purple light reflected
(c)	brighter/ greater contrast/ more focused /greener ✓ ...... explained ✓	2	
	total	10	

8 (a)(i)	One loop ✓ nodes and antinodes labelled ✓	2	
(ii)	0.8 (m) ✓ ecf from (a)(i)	1	
(iii)	= 440 x 0.8 ✓ = 352 (m s^{-1}) ✓ ecf from (a)(ii)	2	
(b)	N = kg m s^{-2} ✓ for coherent development✓	2	
(c)(i)	different mass per unit length (thickness/density) ✓ thicker string .... lowest note ✓	2	
(ii)	equal force on neck/ won't distort instrument/ easier to bow ✓ or other **mechanical** reason	1	
	total	10	

9 (a)(i)	constant speed ✓ equal distance in equal times ✓	2	or no forces acting horizontally
(ii)	accelerating ✓ increasing distances in equal times ✓	2	or gravity is acting vertically
(b)(i)	$t = x/v$ ✓ so $t^2 = x^2/v^2$ ✓	2	$t^2 = x^2/v^2$ 2 marks
(ii)	$y = \frac{1}{2}gt^2$ rearranged ✓ ...... to give $t^2 = 2y/g$	1	
(iii)	$x^2/v^2 = 2y/g$ rearranged ✓ ..... to give $v^2 = x^2g/2y$	1	
(c)	$v^2 = ((4.0)^2 \times 9.8)/(2 \times 1.5)$ ✓ = 52 (52.27) $v = 7.2$ ✓ (m s^{-1}) 3 s.f. max	2	
	total	10	

10 (a)(i)	arrow backwards ✓ labelled 'drag' / air or wind resistance (not just 'friction') ✓	2	through common point, drawn **on** the aircraft
(ii)	thrust = drag ✓ lift = weight ✓ forces must be 'balanced' idea/ no acceleration ✓	3	
(b)(i)	appropriate **velocity** vector arrows to scale ✓ to match Fig. 10.1	1	must have arrows
(ii) 1	method mark ✓ 11 m s^{-1} (10.8) ✓ (10.5 to 11.5 by diag)	2	by Pythagoras or measurement
(ii) 2	method mark ✓ 21.8° ✓ (20° to 25° by diag)	2	by trig or measurement
	total	10	
11 (a)(i)	clear statement of measurement ✓	1	
(ii)	sensible estimate **with unit** ✓ (check for appropriateness)	1	UP
(b)(i)	diagram labelled - could be set up ✓✓✓ some errors or omissions ✓✓ some plausible attempt made ✓	3/2/1	
(ii)	radiation sent out ✓ pulse ✓ reflected and received ✓ time delay measured/recorded ✓	4	what would need to be done in this case.. addressed (prose)
(c)(i)	s = vt ✓ stating specifically what v represents here ✓ time delay halved ✓	3	depends on example selected (analysis)
(ii)	for 2 relevant sources of error ✓✓	2	or 1 factor and the consequence
	total	14	
12 (a)	For a **situation** where a quantum phenomenon is observed✓	1	if not a quantum phenomenon ... zero marks total
(b)	clear labelled diagram ✓✓✓ ...with some minor omissions or errors ✓✓ .... for some attempt made ✓	3/2/1	
(c)	for four separate relevant and correct items of description ✓✓✓✓	4	
(d)	read as a whole ... upto 4 marks for relevant **quantum** ideas ✓✓✓✓	4	
	total	12	
Qo WC	✓✓✓✓	4	Judged solely on written communication in questions 11 and 12

Mark Scheme 2863/1
January 2004

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Question	Expected Answers	Marks
1 (a)	J ✓	1
(b)	N ✓	1
2	$\Delta\theta = Q/mc = 3.5 \times 10^4 / 0.21 \times 4200$ ✓ $= 40\,°c$ $(39.7\,°c)$ ✓ Final temperature $= 40 + 20 = 60\,°c$ ✓ $(59.7\,°c)$ marking points 'stand alone'	3
3 (a)	$Q = CV$ ✓ $\rightarrow E = \frac{1}{2}CV * V$ ✓ $= \frac{1}{2}CV^2$	2
(b)	Graph starting at 0,0 ✓ and curving upwards ✓	2
4 (a)	e.g. galaxies *receding*/ (cosmological) redshift, Hubble's Law ✓	1
(b)	Link to early Universe, e.g.: microwave radiation remnant of era of recombination (accept remnant of 'big bang') ✓ present distribution reflects earlier distribution✓ (therefore, any large scale anisotropy in early universe would be reflected in variation in background AW)	2
5 (a)	$pV = nRT$ ✓ $\rightarrow V = nRT/p = 1 \times 8.31 \times 300 / 1.0 \times 10^5$ ✓ $=0.0249\ m^3$ (can work backwards or use $pV = NkT$)	2
(b)	$1.0 \times 10^5 \times 0.025 = p_2 \times 0.020$ ✓ $p_2 = 1.3 \times 10^5\ Pa$ ✓ (accept 1.25×10^5) candidates can use their answer to 5 (a) (ecf) (e.g. 1.2×10^5 if 0.0249 used).	2
6 (a)	$I = V/R = 6/5.6 \times 10^3$ ✓ $= 1.1 \times 10^{-3}A$ = (about) 1 mA ✓	2
(b)	$I = 1.1 \times 10^{-3} \times e^{-1} = 1.1 \times 10^{-3} \times 0.37$ ✓ $= 0.4\ mA$ ✓ (accept rule of thumb third, answers using 1 mA & answers using decay equation)	2
	Section A total	20

7 (a) (i) Max depth = 15m ✓   1
(a) (ii) Amplitude = 5 m ✓   1
(a) (iii) Gradient at t = 6 hours ✓ correct reading from graph✓ answer worked to   3
3.0 m hr^{-1} ✓ (answers in range 2.5 m hr^{-1} to 3.5 m hr^{-1})
(b) time period from graph = 12.5 hrs ✓ $f = 1/T = 1/12.5$ ✓ = 0.080 hr^{-1} ✓   3

(c) shading or lines drawn on graph ✓ answer in range of 15.5 hrs to 16.5 hrs ✓   2

(d) d = 10 + 5 sin (2πsin 0.080 * 9.5) ✓ = 5.0 m ✓   (allow ecf from a(ii) and b)   2
or sin varies between +1 and −1 ✓ so lowest value is 10 − A (this allows incorrect value
for A to ecf) ✓

8 (a)(i) Δp = 280 x 55 − 280 x 0✓ = 15 400✓ kg ms^{-1} ✓   3

(a) (ii) f = ma = 280 x (55/0.25) ✓ = 61600 N ✓ (or use F = $\frac{mv - mu}{t}$)   2

a(iii) argue from Newton 3 or conservation of momentum leading to a force on the plane ✓
this makes the plane move down✓ (as plane is much more massive so
acceleration/movement much less than that of the pilot) . (Accept plane won't move   2
because its on the ground for second mark)
                                                                                                3

(b) ½ mv^2 = mgΔh ✓ Δh = v^2 / 2g = 55^2/ 19.6 ✓ = 154 m ✓ S.F. penalty.
Or suitable equation of motion chosen ✓ values substituted ✓ evaluation✓

(c) Collisions between pilot and particles ✓ momentum/ direction/ velocity change of
particles during collision ✓   change of momentum of particles exerts force on pilot. ✓   3

9 (a) 250 x 50 = 12500 J ✓   1

(b) number of molecules = 5 x 6.02 x 10^{23} /18 ✓ = 1.67 x 10^{23} ✓   2

(c) E = 12500/1.7 x 10^{23} ✓ = 7.35 x 10^{-20} ✓ J (or 7.48 x 10^{-20} if 1.67 x 10^{23} used)   2

(d) kT = 1.4 x 10^{-23} x 373 = 5.2 x 10^{-21} J✓   1

(e) (i) 5.2 x 10^{-21}/7.5 x10^{-20} = 0.07 ✓. (ecf)   1
(ii) Argument from average energy✓ explanation of why there is a range of energies e.g.
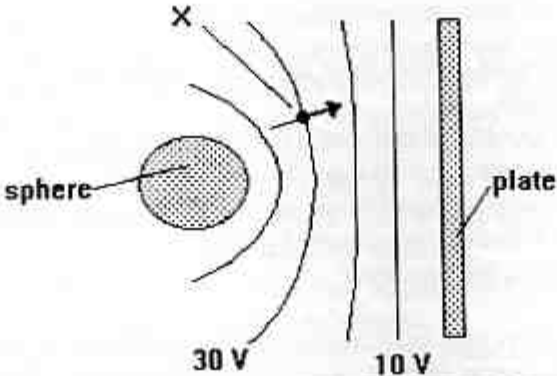molecular collisions or 'getting lucky' ✓ (or Boltzmann arguments)   2

10 (a) (i) $V_{grav} = -6.67 \times 10^{-11} \times 5.98 \times 10^{24} / 6.38 \times 10^{5}$ ✓ $= -6.252 \times 10^{7}$ ✓ J kg^{-1} 2
          Own value needed.

(a) (ii)   Calculating $V_{grav} = -6.27 \times 10^{7}$ ✓ J kg^{-1} using this to give ratio 6.27/6.25 = 1.003(2) ✓   2
         Own value needed.
         OR: explanation leading to 6.38/6.36 ✓ = 1.0031 ✓

a(iii)   Gravity is always attractive (AW) ✓ hence it always takes energy/work to separate   2
       gravitationally bound masses. At infinity the energy 'stored' is zero therefore an object
       in a field will be in a potential well. ✓ (AW)

(b) $g = (-)GM/r^2$ ✓   1

(c) (i) $g = -6.67 \times 10^{-11} \times 5.98 \times 10^{24} /(6.36 \times 10^{6})^2$ ✓ $= 9.86$ ✓ N kg^{-1} ✓   3
(ii)   Value for potential depends on r whereas field strength depends on r^2. ✓ Hence field   2
       strength more sensitive to changes in r ✓ or evaluate ratio ✓ (OWTTE)
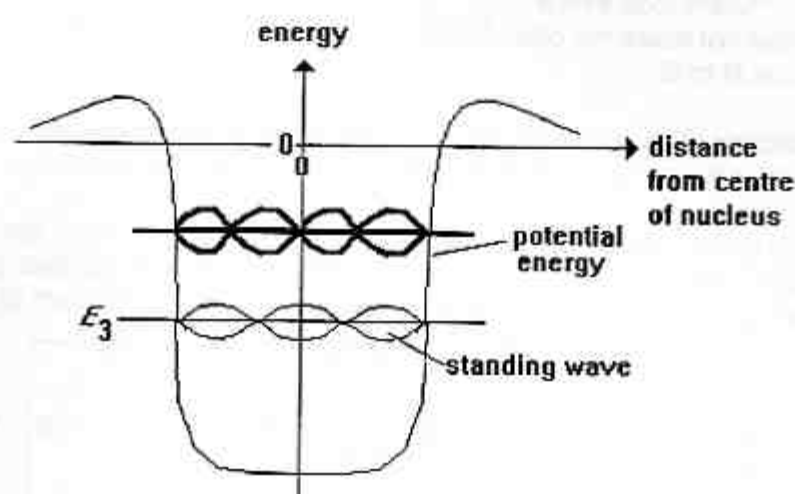
       QWC marks on questions 8 a(iii), 8 (c) , 9 e (ii)   ✓✓✓✓   4
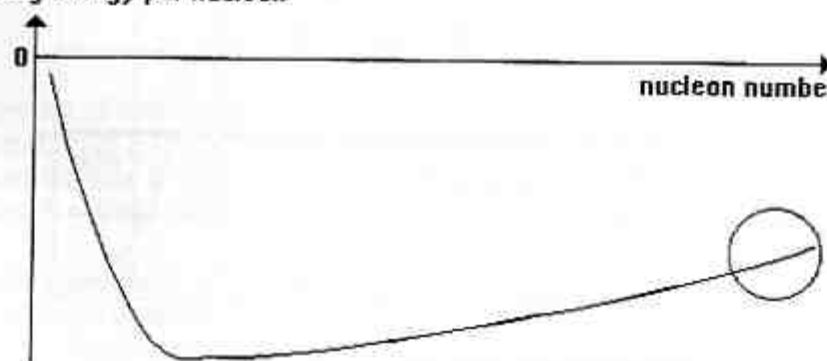
Section B total: 50 marks
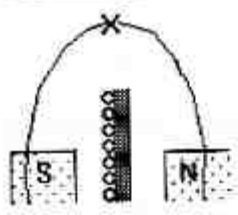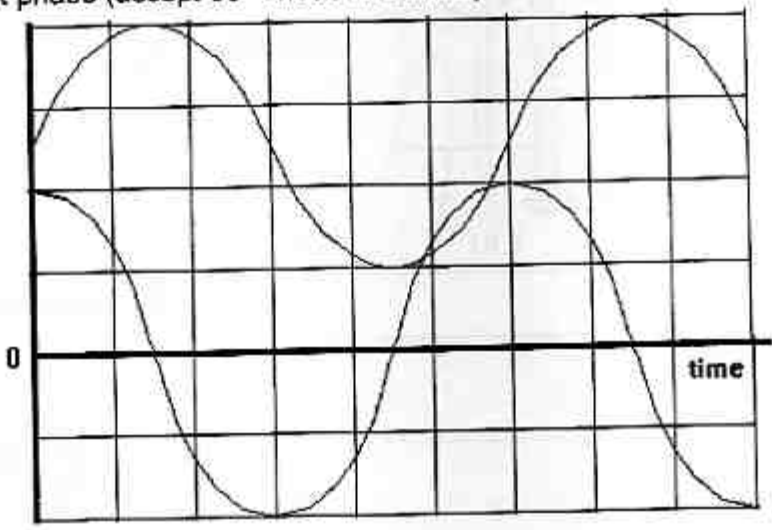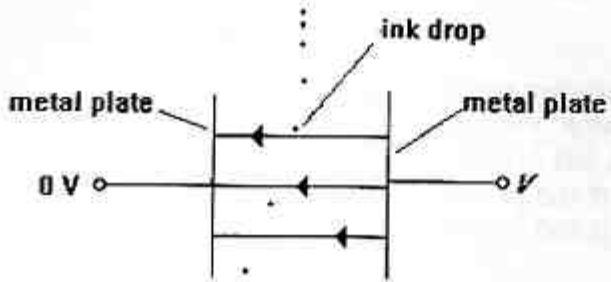
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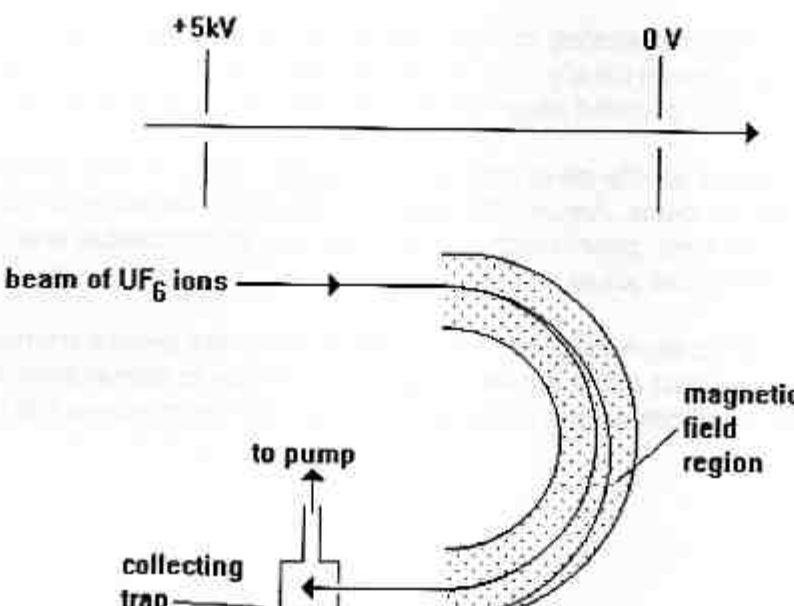|		
1	s^{-1}	1
2	A	1
3	10^3	1
4 (a)	A	1
4 (b)	E is electric field (strength) / force on unit charge	1
5 (a)	at right angles to equipotential through the point (by eye) pointing away from sphere ACCEPT curved field lines which have the correct direction at X 	1 1
5 (b)	0 V	1
6	A C	1 1

7(a)	B	1
7(b)	C	1
8	higher energy level standing wave to fit potential well more than two antinodes	1 1 1

9 (a)		1
	binding energy per nucleon graph as shown, by eye	

9 (b)	total binding energy = $56 \times 8.8 \times 10^6 = 4.93 \times 10^8$ eV ecf incorrect eV: energy = $4.93 \times 10^8 \times 1.6 \times 10^{-19} = 7.9 \times 10^{-11}$ J (steps clearly shown to earn marks)	1 1
9 (c)	$E = mc^2$ ecf incorrect E: $m = E/c^2 = 7.9 \times 10^{-11}/9 \times 10^{16}$ $m = 8.8 \times 10^{-28}$ kg (1×10^{-10} J gives 1×10^{-27} kg)	1 1

10 (a) (i)		1
10 (a)(ii)	Any complete loop which • does not cross the other loops • joins N to S	1
10 (b)	substitution: $1.2 \times 10^{-3}/0.25$ answer: 4.8×10^{-3} V	1 1
10 (c)(i)	correct period and sinusoidal shape, any amplitude average value of zero correct phase (accept 90° ahead or behind) 	1 1 1
10 (c)(ii)	Description: any two of the following, 1 mark each • wind more turns on the coil • use a stronger magnet • increase the area of the turns • decrease the air gap between the poles • wind coil on an iron former • mechanical arrangement (e.g. lever) to increase displacement Explanation: each modification increases flux linkage (change) of the coil	2 1

11 (a)	$Q = ne$ (eor) $n = 8 \times 10^{-10} / 1.6 \times 10^{-19} = 5.0 \times 10^{9}$	1 1
11 (b)(i)	positive EITHER so that right-hand plate becomes positively charged repelling positive charge on drop OR left-hand plate becomes negatively charged to attract positive charge on the drop OR potential decreases as drop moves to the left resulting in drop gaining KE as it moves that way	0 1
11 (b)(ii)	horizontal lines equally spaced (accept correct edge-effects) arrow to the left 	1 1 1
11 (c)(i)	statement of formula: $E = V/d$ elimination of E to obtain required expression accept formula $E = V/d$ derived from expression for [2] accept $F = QV/d$ for [1]	1 1
11 (c)(ii)	correct substitution of powers of 10 ecf incorrect powers of ten: $V = \dfrac{Fd}{Q} = \dfrac{3.6 \times 10^{-6} \times 15 \times 10^{-2}}{0.8 \times 10^{-9}} = 675$ V (accept 680 V)	1 1

12 (a)(i)	number of X-rays = 120 ecf: total dose equivalent = $120 \times 16 \times 10^{-6} = 1.9 \times 10^{-3}$ Sv ecf :risk = $1.9 \times 10^{-3} \times 3 = 0.0058$ %	1 1 1
12 (a)(ii)	cancers = $0.0058 \times 55 \times 10^6 / 100 = 3200$ (0.006% gives 3300)	1
12 (a)(iiii)	[1] + [1] per valid statement backed by correct calculation, up to [4] No ecf: e.g. • annual dose equivalent from X-rays is 32 μSv • 32/2000 = 0.016 of dose equivalent from background (ora) • risk of background is unavoidable (owtte) • and will lead to $2 \times 10^{-3} \times 60 \times 0.03 \times 55 \times 10^6 = 200\ 000$ cancers • lifetime X-ray dose similar to annual background dose • so any cancer is much less likely to come from X-ray (ora)	4
12 (b)(i)	proposal: d.e. $\times$ distance^2 = constant shown clearly calculations: -1 per error, maximum -2 $2.6 \times 10^{-6} \times 0.25^2 = 0.163\ (\times 10^{-6})$ $0.95 \times 10^{-6} \times 0.41^2 = 0.160\ (\times 10^{-6})$ $0.27 \times 10^{-6} \times 0.77^2 = 0.160\ (\times 10^{-6})$	1 2
12 (b)(ii)	any of the following, maximum [2] • X-ray emitter acts as a point source (owtte) • photons spread out evenly in all directions/in a cone • X-ray photons not absorbed by air • dose equivalent depends on photons per square metre (owtte) • doubling distance quadruples area for photons to pass through (owtte)	2
12 (b)(iii)	dose equivalent per X-ray = $0.2 \times 10^{-3}/4000 = 5 \times 10^{-8}$ Sv X-ray dose equivalent = $0.16 \times 10^{-6}/x^2$ $x = (0.16 \times 10^{-6}/5 \times 10^{-8})^{0.5} = 1.8$ m	1 1

13 (a)(i)	$+4.8 \times 10^{-19}$ C	1
13 (a)(ii)	$m = (235 + 6 \times 19) = 349u$	1
	ecf incorrect m: mass $= 349 \times 1.7 \times 10^{-27} = 5.9 \times 10^{-25}$ kg (NOT 6×10^{-25})	1
	($235u$ gives 4.0×10^{-25} kg)	
13 (b)(i)	EITHER	1
	(accelerating) force = charge $\times$ electric field (owtte)	
	OR	
	(potential) energy = charge $\times$ potential (owtte)	
	OR	
	charged particles repelled / attracted by charges on electrodes	
13 (b)(ii)	pair of electrodes / colinear tubes	1
	5 kV apart	1
	ions move from high potential to low potential	1
13 (c)(i)		1
13 (c)(ii)	vacuum means no collisions with air molecules (owtte)	1
	to alter velocity / charge of ions	1
	which would result in a different path in magnetic field	1
	Quality of Written Communication	4

Mark Scheme 2865
January 2004

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Qn		Expected Answers	Marks	Additional guidance
1 (a)		Any long random linear molecular structure ✓	1	Chemical type chains OK, or just zigzags
(b)	(i)	Not brittle/doesn't crack/deforms before breaking/ absorbs energy on breaking/ AW✓	1	Force or energy argument acceptable for (b)(ii) and (iii)
	(ii)	Molecules tightly wound ✓ ; Strongly bonded / difficult to separate helical 'strands'✓	2	
	(iii)	Molecules separate ✓ ; Less strongly bonded ✓	2	
(c)	(i)	Virtually all water ✓	1	
	(ii)	Very few bonds between protein strands to break ✓	1	
		Total:	8	
2 (a)		$70 \text{ kJ mol}^{-1} = 70 \times 10^3/6.0 \times 10^{23}$ J per molecule ✓m $= 1.17 \times 10^{-19}$ J / molecule $\approx 1.2 \times 10^{-19}$ J / molecule✓e ora	2	Must have 1.17×10^{-19} J for second mark
(b)		(i) kT is an energy, in J ✓ ; so E/kT is dimensionless AW ✓	2	'Argument of e must be dimensionless' gets ✓ only
		(ii) At 500 K, $E = 15kT$ while at 255 K, $E = 30kT$ ✓ ; Only processes with $15<E/kT<30$ happen at an appreciable rate AW✓	2	E/kT not big enough at 255 K would gain ✓ only
(c)		(i) Ratio of $f_B = 7.51 \times 10^{-11}/3.95 \times 10^{-11} = 1.90$ ✓m ; ≈ 2 so rate is roughly doubled ✓	2	Ora e.g. 'should be doubled $= 7.9 \times 10^{-11}$ at 373 K which is close'
		(ii) reaction rate depends on number of molecules having enough energy to react ✓ ; Boltzmann factor gives fraction of molecules with enough energy ✓	2	
		Total:	10	
3 (a)		Alcohol would boil/ could not read thermometer in food✓	1	Anything plausible
(b)		12 mV is much too small to read on 2.5 V scale ✓	1	
(c)		Gradient not constant ✓ ; Show/ calculate that emf < 1.25 V ✓	2	'May' allows correction e.g. with lookup table
(d)		Appreciating that resolution is related to slope of graph✓ ; Resolution greatest near 0°C because same ΔT produces bigger $\Delta \varepsilon$/gradient greatest near 0°C ✓	2	
		Total:	6	

Qn	Expected Answers	Marks	Additional guidance
4 (a)	(i) decreases because field lines further apart ✓	1	
	(ii) $E_{k\,max} = 4000 \times 1.6 \times 10^{-19}$ J		Can use 6.4×10^{-16} J to
	$= 6.4 \times 10^{-16}$ J $\approx 6 \times 10^{-16}$ J ✓m✓e	2	get 1.0×10^{18} s⁻¹ in (iii) get 1.0×10^{18} s^{-1} in (iii)
	(iii) $650/6 \times 10^{-16}$ J $= 1.1 \times 10^{18}$ s^{-1} ✓m✓e	2	(iv) must refer to
	(iv) Energy not all converted to useful output ✓	1	energy.
(b)	Arrow perpendicular to electron path✓ ; Arrow to right✓	2	Inward arrow which is not perpendicular gets one ✓
(c)	(i) Force ✓ ; On charge q moving at velocity v in field B✓	2	
	(ii) Centripetal force/ force needed ✓ ; for particle to move along arc (of radius r)✓	2	(ii) second mark needs equation to be related to this situation
	(iii) Electron starts slow and accelerates/electron gains kinetic energy, so v increases✓ ;		(iii) increased momentum not enough for second mark
	$v \propto r$ (equation 2), so as v increases, r increases ✓	2	
	Total:	14	
5 (a)	High resistance means low conductance/vice versa ✓ ; high conductance base corresponds to low resistance in electrical circuit✓	2	First mark can be stated or implied
(b)	p.d. $= \Delta T$ shared between two different resistances and bigger resistance = egg takes bigger share ✓ ; so T at base of egg (Y) is close to T of pan (X) ✓	2	Can use constant current and Ohm's Law
(c)	Temperature at Y close to that at X ✓ ; At high temperatures, carbonisation takes place/molecules split up completely/AW ✓	2	
	Total:	6	
6 (a)	$E = hf = 6.63 \times 10^{-34} \times 2.45 \times 10^{9}$ J $= 1.62 \times 10^{-24}$ J $\approx 2 \times 10^{-24}$ ✓m✓e	2	Must calculate E to at least 2 sf to show this
(b)	(i) Constant ratio of adjacent/equally spaced values ✓	1	19/24=0.79, 15/19=0.79
	(ii) Test applied to ≥ 2 pairs ✓ conclusion (yes) ✓	2	12/15=0.80, 10/12=0.83 15/24=0.63, 10/15=0.67
	(iii) Use of repeated ratio appropriately to get 1.5 – 1.7✓	1	
(c)	Microwaves absorbed more as they penetrate✓ ; intensity lower as you go further in ✓	2	
	Total:	8	

Qn	Expected Answers	Marks	Additional guidance
7 (a)	$c=f\lambda$ ✓ ; $\lambda = c/f = 3.00\times10^{8}/2.45\times10^{9}$ m $= 0.122$ m ≈ 12 cm ✓s✓e	3	
(b)	Reflect✓	1	
(c)	Whole number of node-node loops✓ ; 6 loops✓	2	Must be 'loopy' and not just a travelling wave
	Total:	6	
8 (a)	(i) $\rho_{Ceres} = 8.7\times10^{20}/4.3\times10^{17} = 2000$ kg m^{-3} ✓ ; $\rho_{Vesta} = 3.0\times10^{20}/7.8\times10^{17} = 3800$ kg m^{-3} ✓ (ii) Densities differ (significantly) so different materials✓	2 1	Sfe penalty here for >3 sig figs.
(b)	(i) Using $T=2\pi r/v$ ✓ ; $\dfrac{2\pi r}{v} = \dfrac{2\pi r}{\sqrt{GM/r}} = \sqrt{4\pi^{2}r^{2}}\sqrt{\dfrac{r}{GM}} = \sqrt{\dfrac{4\pi^{2}r^{3}}{GM}}$ ✓m✓e (ii) $T\uparrow \Rightarrow r\uparrow \Rightarrow v\downarrow$ so Vesta is faster as T is smaller ✓m✓e	3 2	Must relate T to v for second mark in (ii)
(c)	$T = \sqrt{\dfrac{4\pi^{2}r^{3}}{GM}} = \sqrt{\dfrac{4\pi^{2}(35000)^{3}}{6.67\times10^{-11}\times6.69\times10^{15}}}$ s ✓s $= 61600$ s $= 17.1$ hours $\approx$ nearly a day ✓e	2	
(d)	(i) $t = d/c = 3\times10^{11}/3.0\times10^{8} = 1000$ s✓ (ii) control from Earth not possible ✓ ; because of large (2000 s) round-trip time for signals ✓	3	
(e)	(i) $398\times303 = 120\,594$ ✓ » $10\,576$; so compressed✓ (ii) $10\,576$ bytes $= 10\,576 \times 8$ bits $= 84\,608$ bits ✓ ; time $= 84\,608$ bits $/10$ bits s$^{-1} = 8461$ s ≈ 8500 s✓	1 3	Using 120 594 instead of 10 576 is OK in (ii), $\Rightarrow$964752 bits, 96000 s Ignore sfe in (ii)
	Total:	17	
9 (a)	$k=F/x=4.0$ N$/0.10$ m $= 40$ N m^{-1} ✓	1	
(b)	(i) $F \propto x$ as above ✓ ; $a \propto F$ by Newton II ✓ (ii) a in opposite direction to x ✓ ; reference to vector nature ✓	2 2	
(c)	0.7 s $\le T \le 1.0$ s✓	1	Graph gives 0.92 s
(d)	(i) $T = 2\pi\sqrt{1.0\ \text{kg}/40\ \text{N m}^{-1}} = 2\pi \times 0.158$ s $= 0.99$ s ✓s✓e (ii) Rapid changes in $x/v/a$ not modelled ✓ (iii) Use a much smaller time interval✓ ; example of suitable Δt (e.g. 0.01 s or smaller) ✓	2 1 2	Second mark in (iii) could be for explaining why smaller Δt is better.
	Total:	11	
	Quality of Written Communication	4	